NOAA Project Progress Report

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1. Summary of previous work

The main objective of this proposal is to use both Solar-Induced Fluorescence (SIF) and Vegetation Optical Depth (VOD) microwave data, as constraints to drought response of land-surface models. Indeed Land-surface models still suffer from too many biases to correctly predict droughts and extremes.

We first evaluated whether VOD could be used to estimate the differential role of rooting depth and physiological stomatal regulation. Indeed, those two parameters are very difficult to estimate in current land-surface models. If they can be estimated globally, this will provide a new powerful constraint on the response of vegetation and evapotranspiration to weather.

Based on satellite vegetation optical depth (VOD) data from AMSR-E and AMSR2, we have finished the work of: 1) developing a new global map of effective rooting depth (Z_r) to be used to constrain land-surface models, 2) developing a new global map of plant hydraulic conductivity (K_{plant}) proxy, and 3) investigating the coordination between the global rooting depth and K_{plant} estimates as indicators of plant coordination between "rooting" and "physiological" strategies for contending with water stress. Indeed it is unlikely that those two parameters would be independent, but rather would be coordinated. The work is currently in review at Global Biogeochemical Cycles (Liu et al., in review, 2nd round).

The spatial pattern of our rooting depth proxy compares well with previous estimates of rooting depth – yet those previous estimates were based on various assumptions on rooting depths and not directly based on global estimates, as shown in Figure 1 below, which lends us confidence in our derived Z_r proxy.

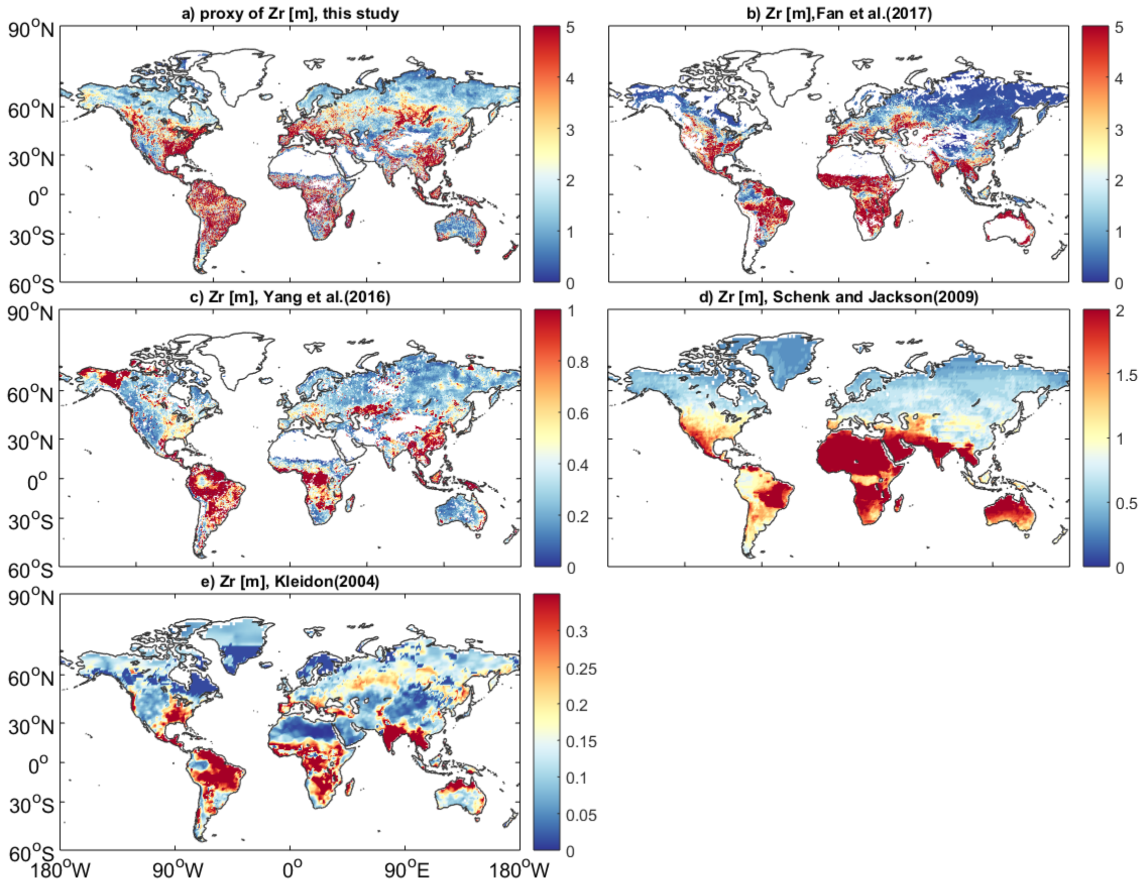

Figure 1 Spatial variations of rooting depth (Z_r) from different sources: a) proxy of Z_r derived from this study; b) effective Z_r from Fan et al. (2017); c) effective Z_r from Yang et al. (2016); d) soil depth containing 95% of all roots (Schenk and Jackson, 2009); and e) hydrological depth of rooting zone in mm H_2O of plant-available water inferred from assimilation of satellite-derived absorbed photosynthetically active radiation (Kleidon, 2004).

Our analysis on the coordination of the two water stress resilience strategies (deep rooting vs. physiological regulation) indicates that physiological regulation appears to be the dominant strategy in Northern high latitudes where open shrubland and (woody) savannas are distributed, this mechanism is coupled with deep rooting in forest and (woody) savanna areas in the tropics, Eastern US and Southeastern China (see Figure 2 below). Meanwhile, some grasslands in the Western US, Central Asia, Northeastern China and Mongolia Plateau may be most susceptible to water stress because neither water stress mitigation strategies are present.

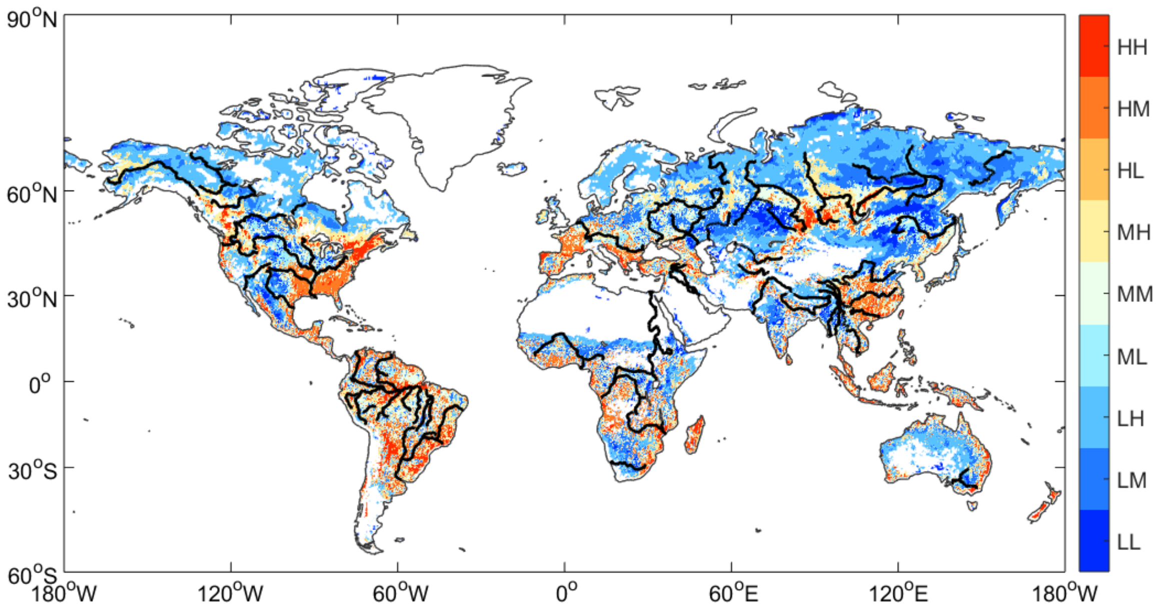

Figure 2. Joint spatial pattern of three levels of rooting depth Z_r and three levels of physiological effects exemplified by whole plant conductance K_{plant} (H=high, M=medium, L=low). The label is composed of the respective level of Z_r and K_{plant}, for instance, HM stands for high level of Z_r and medium level of K_{plant}. Note that in terms of Z_r, high, medium and low levels stand for deep, medium and shallow rooting depth, respectively. The black lines delineate the major rivers obtained from https://worldmap.harvard.edu.

This work improves our understanding of plant water stress strategies at the global scale, and will help enhance large-scale drought prediction and drought impact assessment in Land-surface and Earth system models by improving plant water stress response. The next objective is to use those estiamtes to better constrain the NOAH LSM model.

2. Briefing of ongoing and future work

The second objective is to implement those estimates into the NOAH land surface model. We faced two main roadblocks – first another group at UT Austin had already implemented the assimilation of Solar Induced Fluorescence (SIF) – a proxy for gross primary productivity, which would have been used to constrain the transpiration flux from vegetation and plant water stress. Yet, the group could not share the results before the final publication will be published. Instead of redoing entirely the same work we have been waiting for this release of the SIF upgrade into the NOAH LSM.

The second roadblock we faced is that the funding of the proposal for NOAA has not yet been allocated for a land-surface modeler to collaborate on the proposal. Indeed, right after the proposal, there had been a lot of restructuration at NOAA and the person who was supposed to work on the project was allocated to another project. We therefore do not have yet a person that can directly implement our findings and strategy into the NOAH LSM. Once this is resolved we will be able to implement this into the NOAH LSM.

Given those delays for the use of the NOAH LSM, we decided to first demonstrate a proof of concept into the community land-surface model (CLM). Once a scientist at NOAA is allocated, we will transfer the technology there. We have incorporated solar induced fluorescence (SIF) module into the Community Land Model 5.0 (CLM5.0). One issue was that previous version of the SIF implementation where not compatible with the latest version of CLM. We have implemented the plant hydraulics model (Kennedy et al., 2019), which can be linked to the VOD data, as it resolves the plant vegetation water content (assuming a linear relationship between vegetation water potential and VOD). The plant hydraulics module is easily transportable – it resolves the flow in the plant xylem (sap) and connects it to the transpiration within the stomata. There is no water capacitance as of yet because we considered that it was too small and insufficiently constrained to be used. The implementation of the plant hydraulics module led to improvements of the representation of water stress when evaluated on both in situ sites but also at the global scale.

Our main objective to constrain both the model estimates of carbon and water fluxes by calibrating the CLM5 key parameters, with satellite SIF and VOD data. We filtered the key parameters from literature (see Table 1 below), and have perturbed those parameters and tested their sensitivities in sites with contrasting environments (e.g., wet site in Amazon forest vs. dry site in California). The parameters determining the response of water and carbon fluxes vary from dry to wet environment, and by calibrating the corresponding dominant parameters the carbon/water fluxes estimates will be improved and the CLM5 will be able to capture the effects of extreme events (e.g., droughts, heat waves). We will test the effects of incorporating SIF and the VOD constraints on vegetation water content into CLM5 at site level first, and then move onto larger spatial scale.

Table 1. Key parameters related to SIF and VOD changes in the CLM5

Parameter name	**long name**	**Units**
slatop	Specific leaf area	m^2/g
froot_leaf	Fine root mass per unit leaf mass	gC/gC
stem_leaf	Stem to leaf mass ratio	gC/gC
fracfixers	The fraction of carbon that can be used for fixation	—
leafcn	Leaf carbon:nitrogen target	gC/gN
medlyn_slope	Slope of the stomatal conductance model	—
Kmax	maximum hydraulic conductance (sunlit and shaded leaf, stem, root)	1/s
p50	water potential at 50% loss of conductivity	mmH_2O
root distribution parameter	see Table 11.1 in the CLM5 Tech note	—
g1	inversely related to the marginal carbon cost of water (in Medlyn gs equation)	—

Reference

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